Free Cooling (Economizers)

<Presenter>

PG&E Data Center Demonstrations

Outside air economizer demonstration

- Quantify yearly savings when using air economizers
- Address contamination concerns by measuring particles (contamination) inside and outside of data centers
- Address humidity control concerns by monitoring humidity while taking particle counts.
- PG&E Customers: Bank of America, Sybase, Network Appliance, Kaiser, Gap, OSF (LBNL)

Data Centers

Issue:

- California hosts 5 - 7.5 million ft^2
- Continuous operation of network equipment
- Potential for energy savings is great
- Require ~ 20 to 60 W/ft^2
- Typically do not use economizers
- Outdoor pollutants considered equipment risk
- Actual reliability risk from economizer use is not clear

Air Quality Guidelines

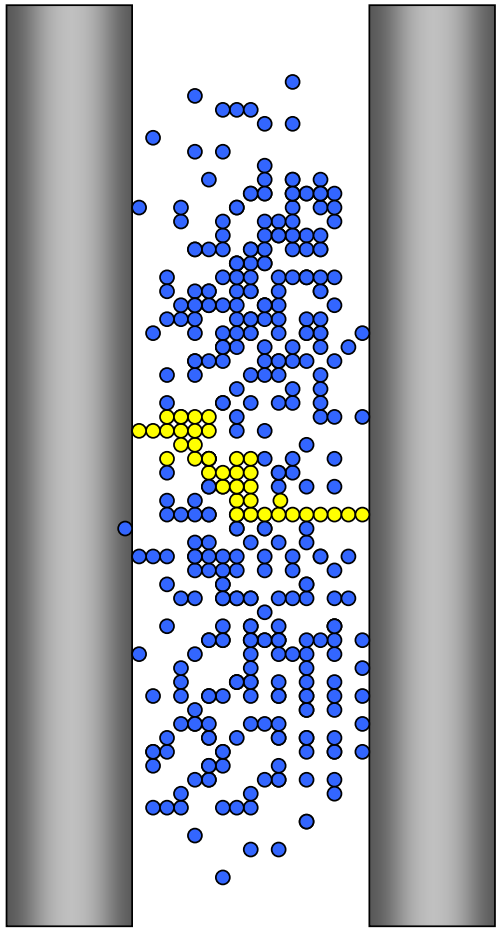
- Limited literature connecting pollutant concentrations to equipment failure
- ASHRAE Technical Committee
  - Design Considerations for Data/Com Equipment Centers
  - Guidelines for particles, gases, humidity
  - Industry Sources: Telcordia GR-63-CORE/IEC 60721-3-3
  - Designed for telephone switching centers
  - Based on research over 20 years old
- Identified guidelines based on 20 year old research

Contaminants	Concentration
Airborne Particles (TSP)	20μg/m^3
Coarse Particles	<10μg/m^3
Fine Particles	15μg/m^3
Water Soluble Salts	10μg/m^3 max-total
Sulfate	10μg/m^3
Nitrites	5 μg/m^3
Total	55 μg/m^3

Current Leakage

Only documented pollutant problem

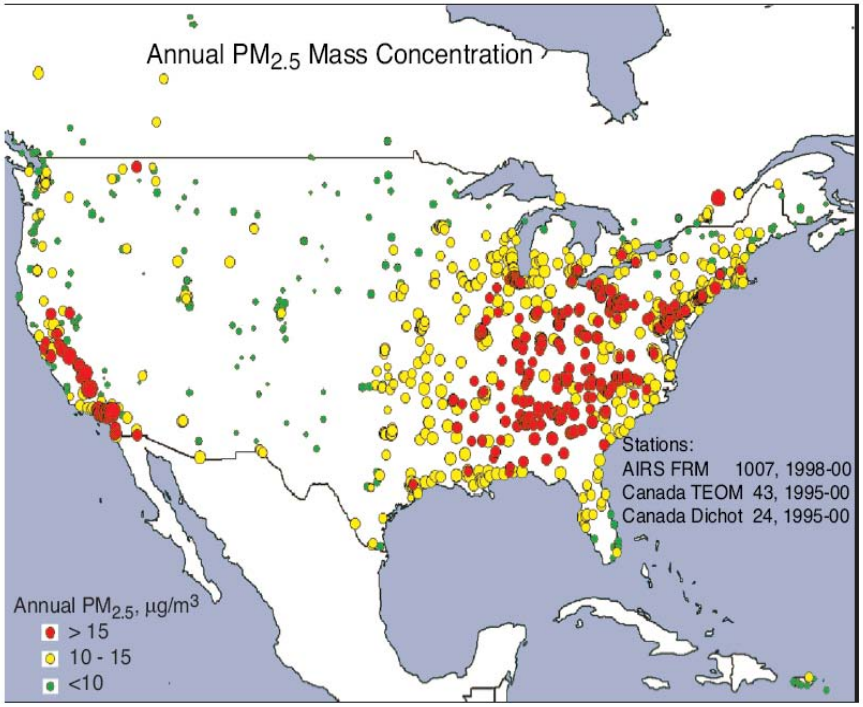
- Deposited particles bridge isolated conductors
- Increased RH cause particles to absorb moisture
- Particles dissociate, become electrically conductive
- Causes current leakage
- Can damage equipment

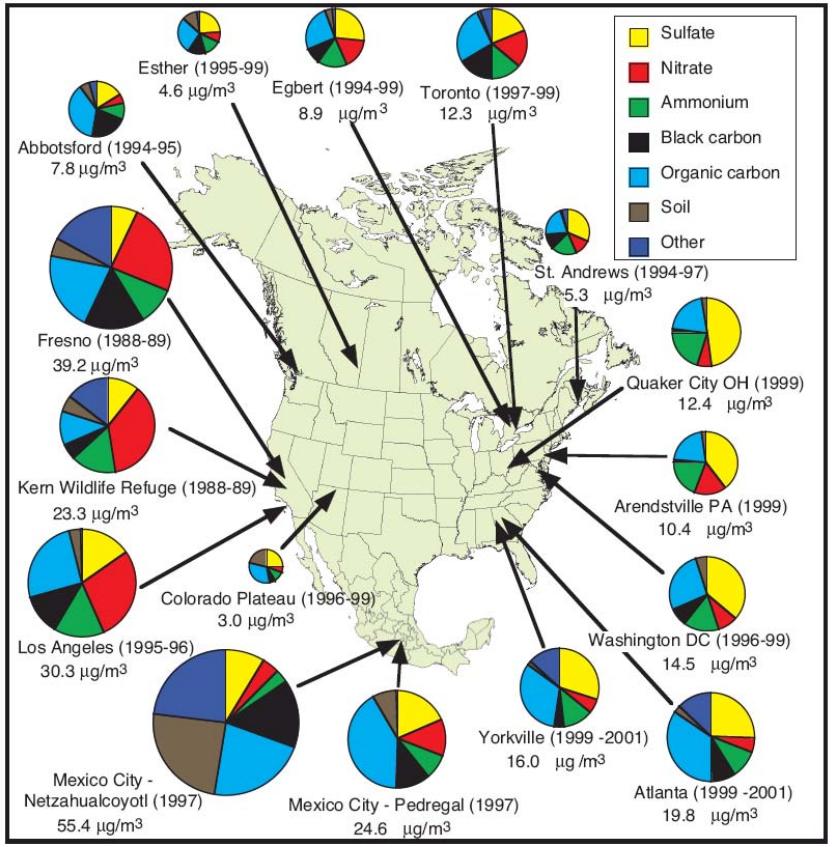


Outdoor Pollutant Concentration

Potential ionic particles of concern:

- **Sea Salt**
- **Nitrates**
- **Sulfates**





Reliability Risk?

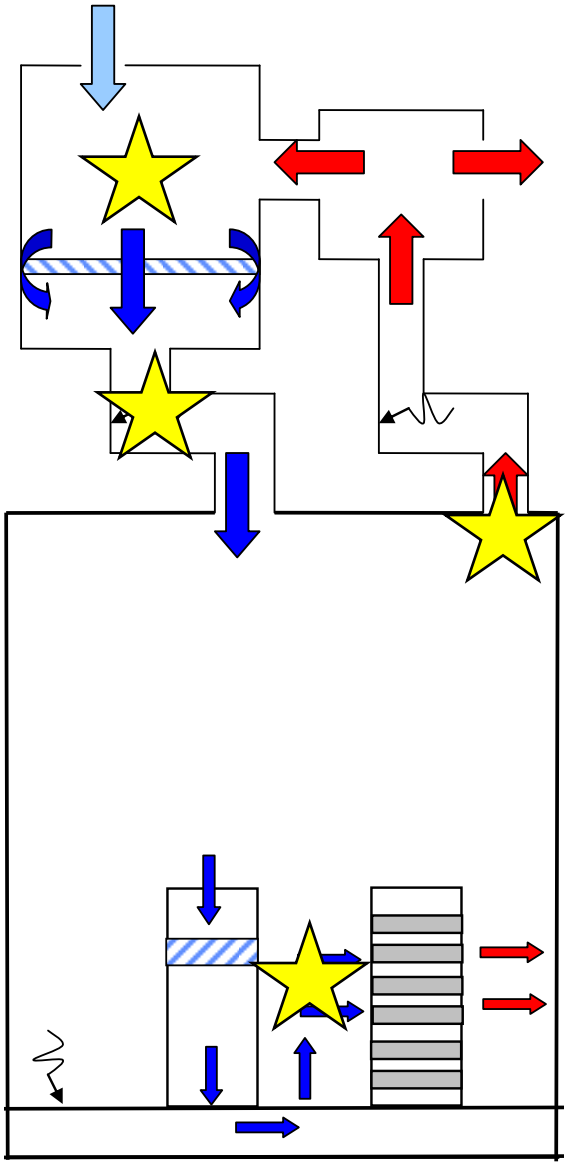
Objective:

- Determine PM concentration in data centers
- Assess influence of outdoor PM concentration
- Evaluate economizer affect on PM exposure
- Identify removal efficiency of PM in different data center designs
- Compare PM concentrations to guideline limits

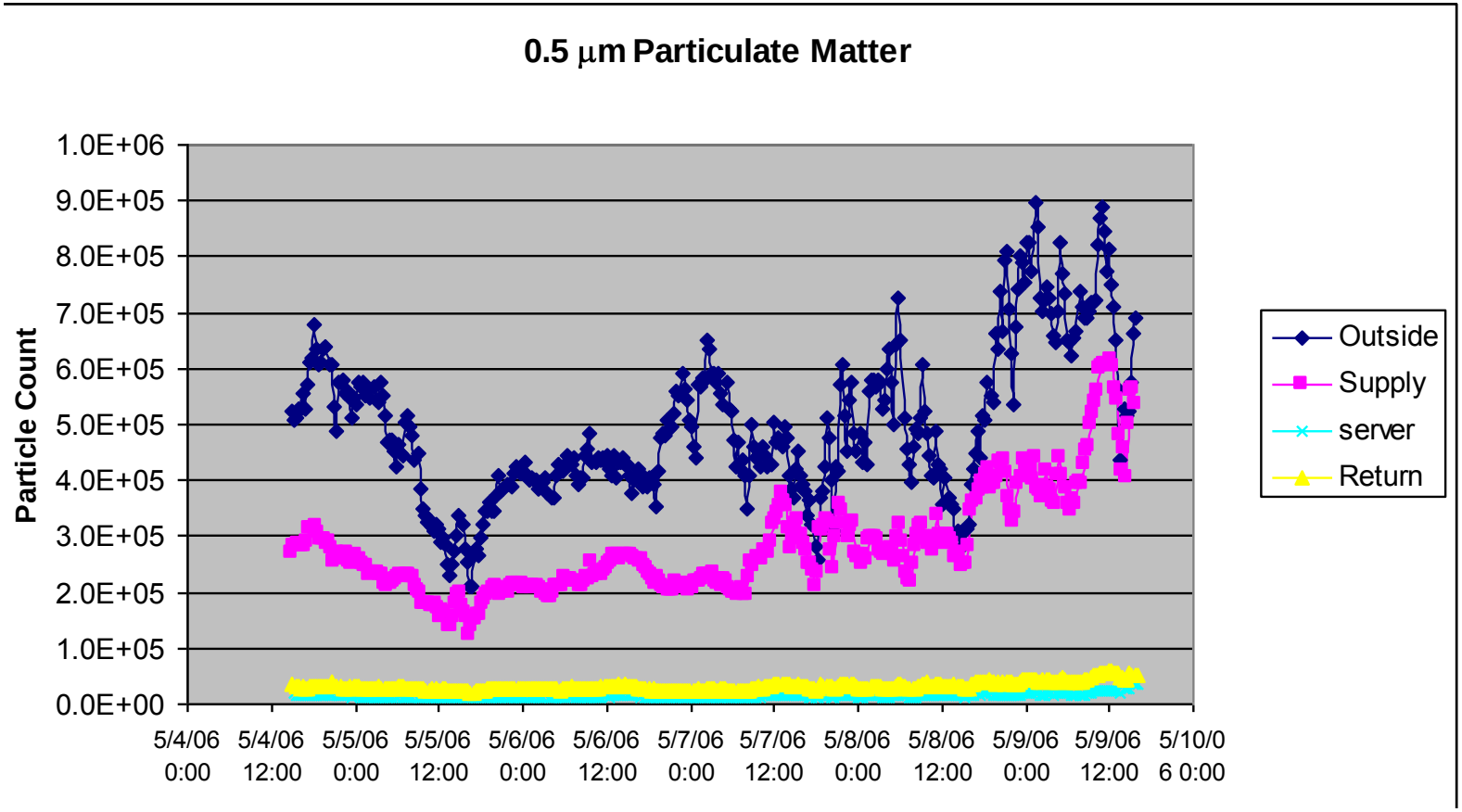
Monitoring Protocol

Approach:

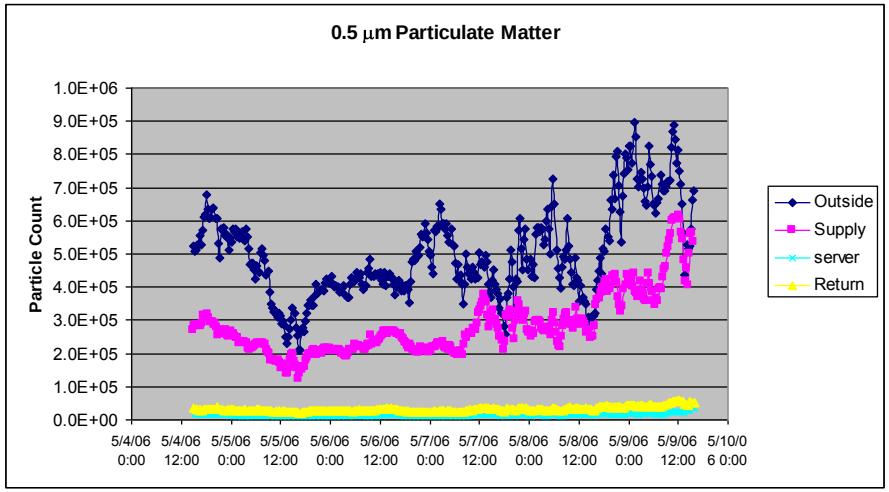
- Measure data center PM exposure
- Determine indoor proportion of outdoor particles
- MetOne optical particle counters
- Size resolution
  - 0.3 μm, 0.5 μm, 0.7 μm, 1.0 μm, 2.0 μm, 5.0 μm
- Full week measuring period
- Measure at strategic locations

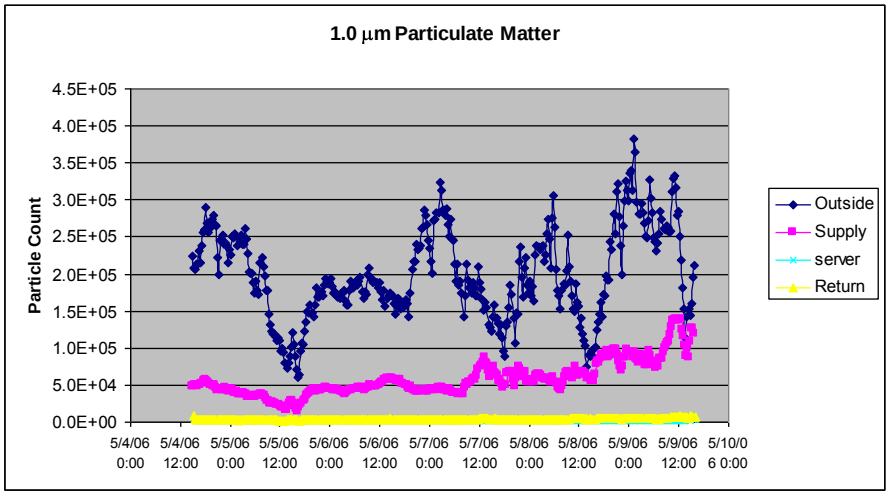


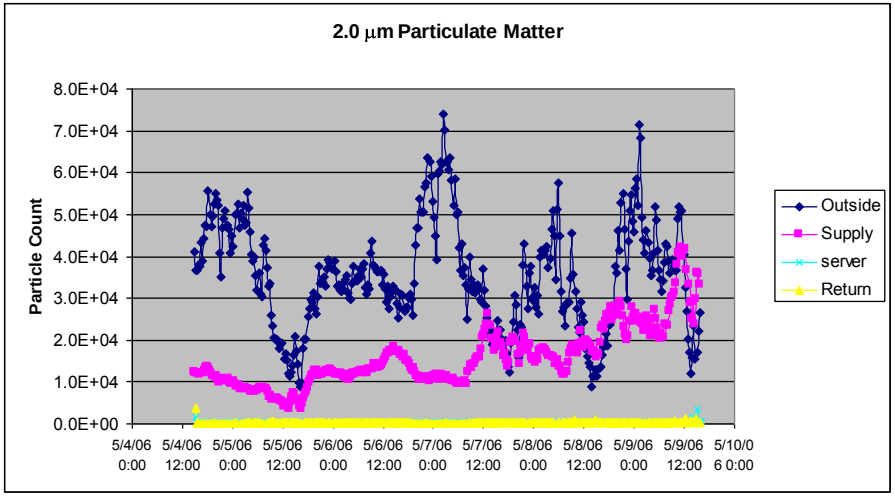
Early results look good

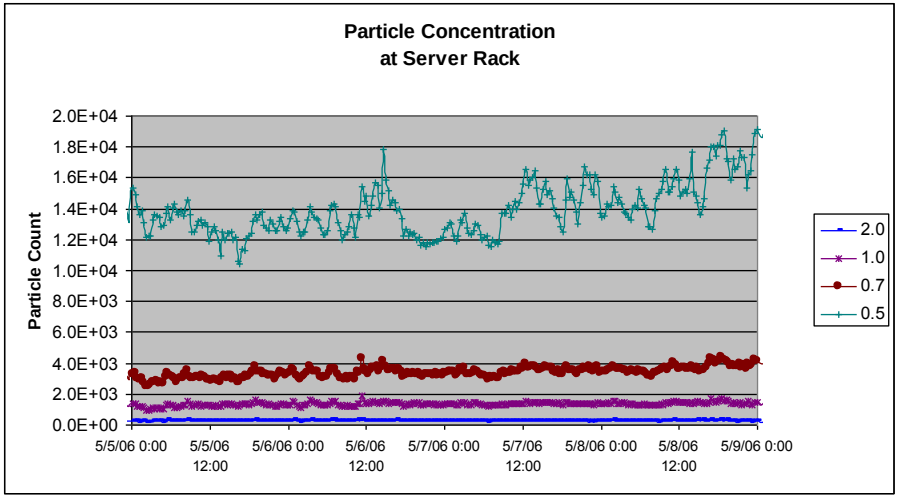


Berkeley Lab Results





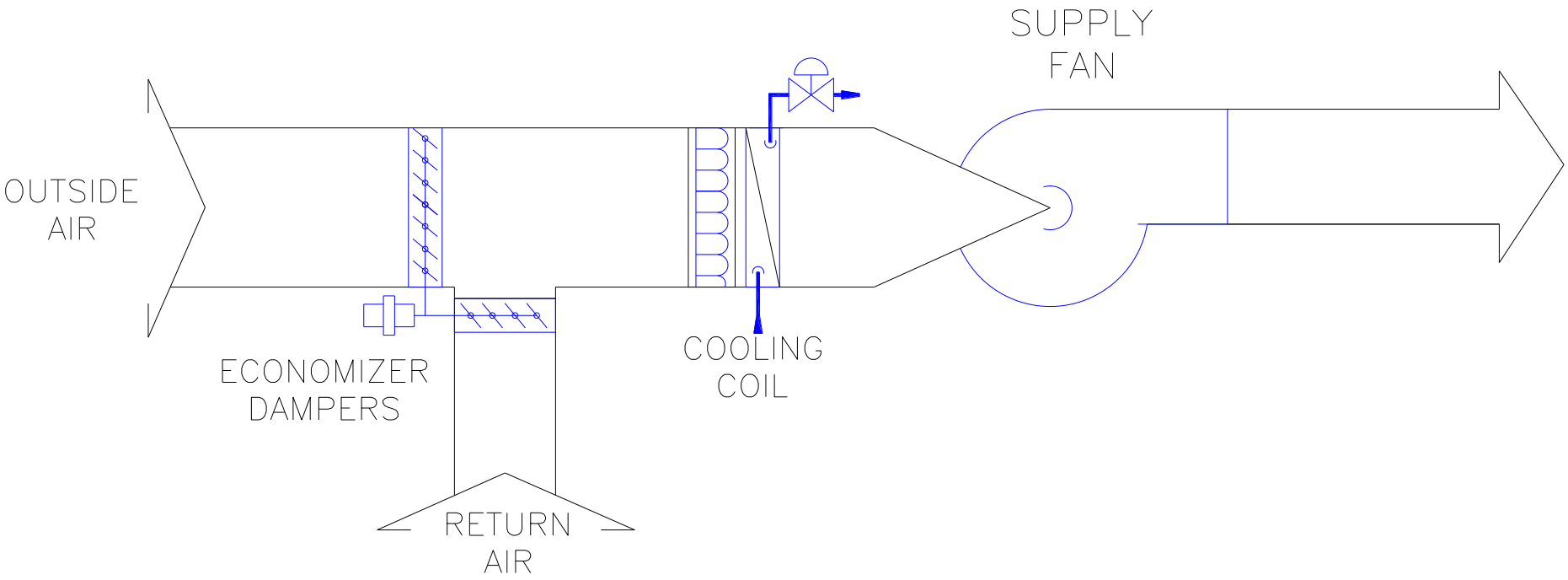




Monitoring Sites

- LBNL
  - Berkeley
  - Oakland Scientific Facility
- Kaiser
- Network Appliance
- Bank of America
  - San Francisco
  - Concord
- Sybase
- Oracle
- Sun Microsystems
- Equinix
- AT&T
- Agilent
- IRS
- Cisco
- Cheveron
- Hewlett Packard
- Cisco
- Chlorox

Air-side economizer



Air-Side Economizer issues

- In California many hours of free cooling
- Concerns over contamination
- Concerns over humidity control
- ASHRAE is addressing these concerns
- LBNL demonstration studied the issues

Design conditions at the zone

Table 2.1
Class 1, Class 2 and NEBS Design Conditions

Condition	Class 1 / Class 2		NEBS	
	Allowable Level	Recommended Level	Allowable Level	Recommended Level
Temperature control range	59°F – 90°F[a,f] (Class 1) 50°F – 95°F[a,f] (Class 2)	68°F – 77°F[a]	41°F – 104°F[c,f]	65°F – 80°F[d]
Maximum temperature rate of change	9°F. per hour[a]		2.9°F/min. [d]	
Relative humidity control range	20% - 80% 63°F. Max Dewpoint[a] (Class 1) 70°F. Max Dewpoint[a] (Class 2)	40% - 55%[a]	5% to 85% 82°F Max Dewpoint[c]	Max 55%[e]
Filtration quality	65%, min. 30%[b] (MERV 11, min. MERV 8)[b]			

[a]These conditions are inlet conditions recommended in the ASHRAE Publication *Thermal Guidelines for Data Processing Environments* (ASHRAE, 2004).
[b]Percentage values per ASHRAE *Standard* 52.1 dust-spot efficiency test. MERV values per ASHRAE Standard 52.2. Refer to Table 8.4 of this publication for the correspondence between MERV, ASHRAE 52.1 & ASHRAE 52.2 Filtration Standards.
[c]Telecordia 2002 GR-63-CORE
[d]Telecordia 2001 GR-3028-CORE
[e]Generally accepted telecom practice. Telecom central offices are not generally humidified, but grounding of personnel is common practice to reduce ESD.
[f]Refer to Figure 2.2 for temperature derating with altitude

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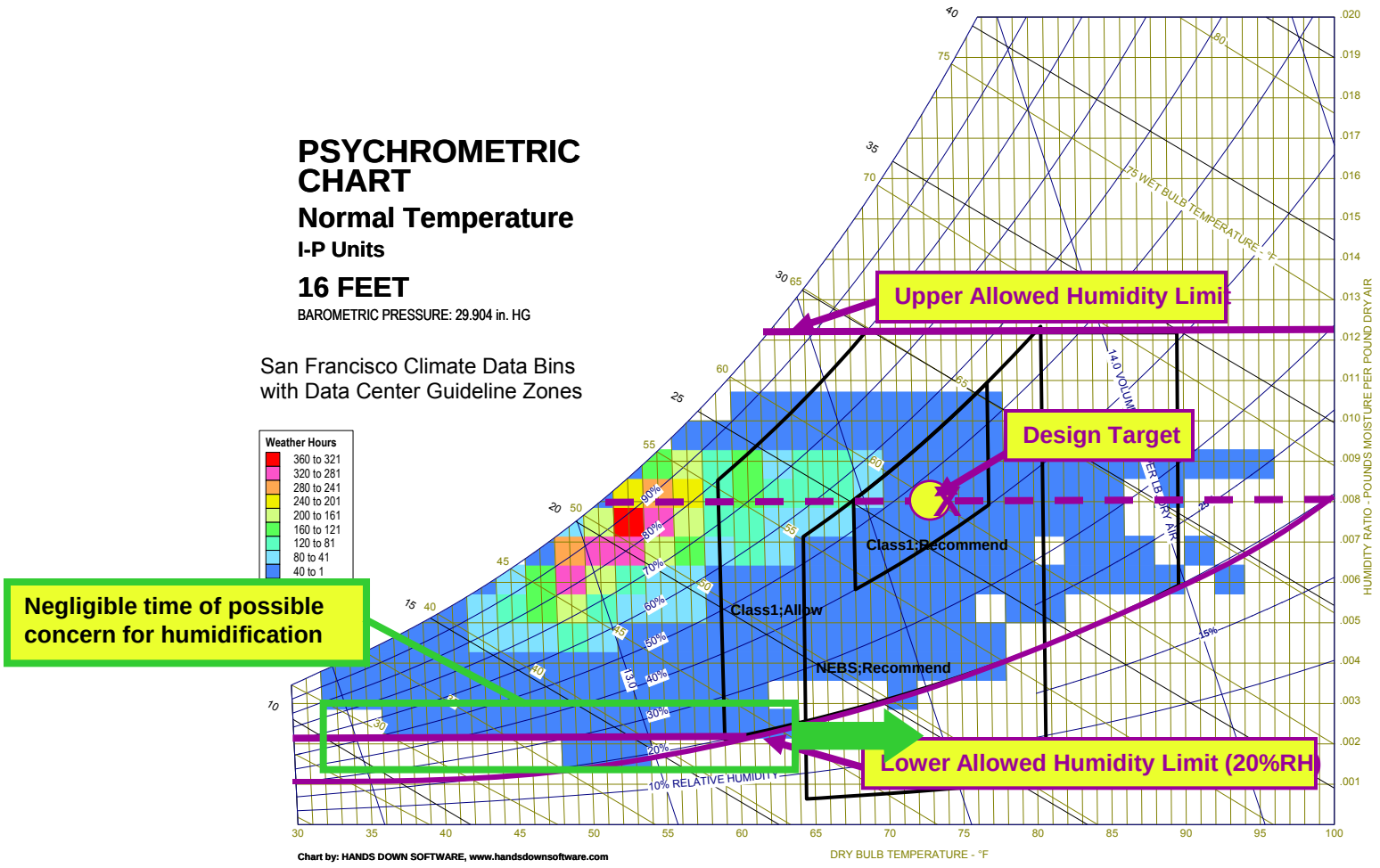
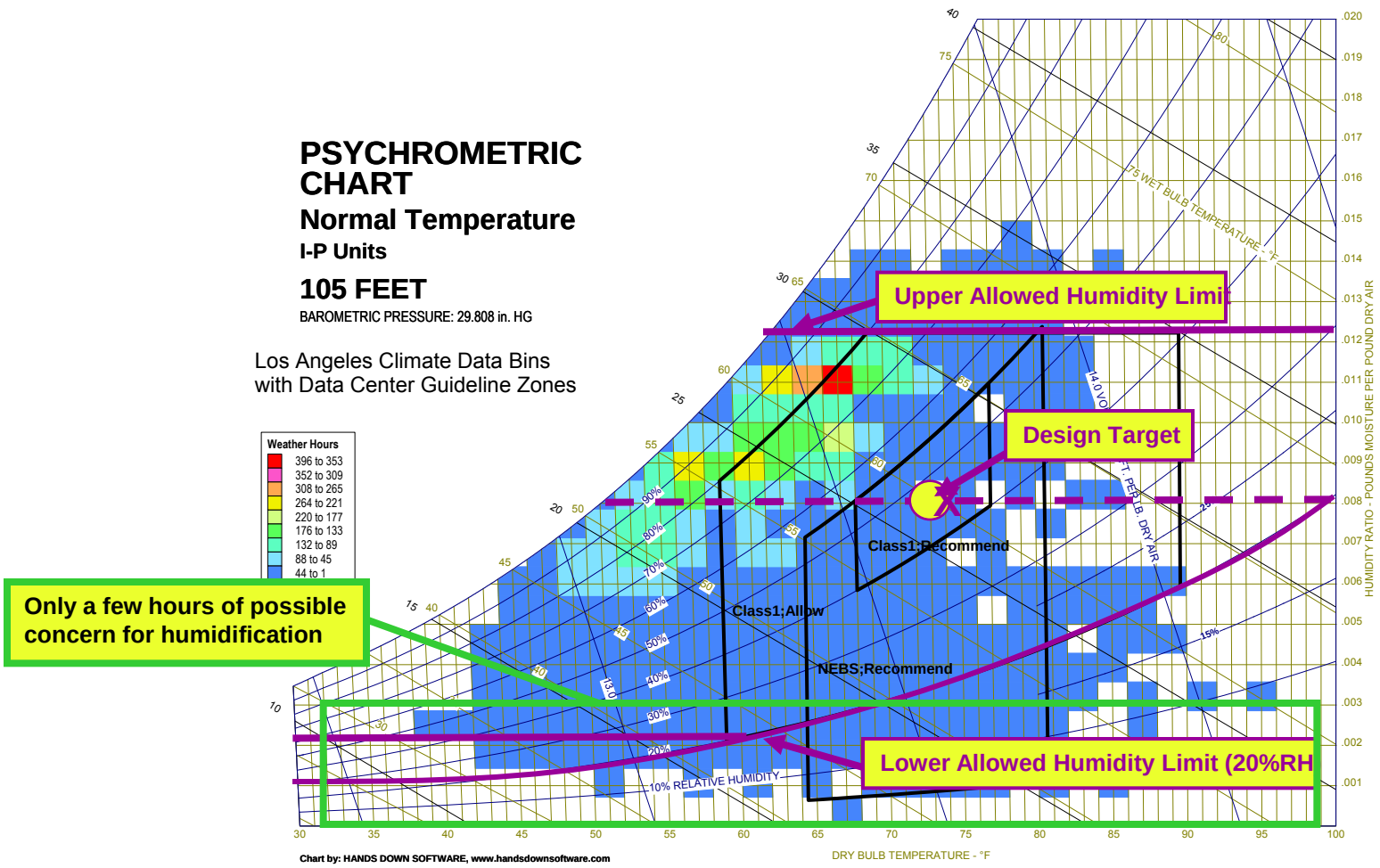
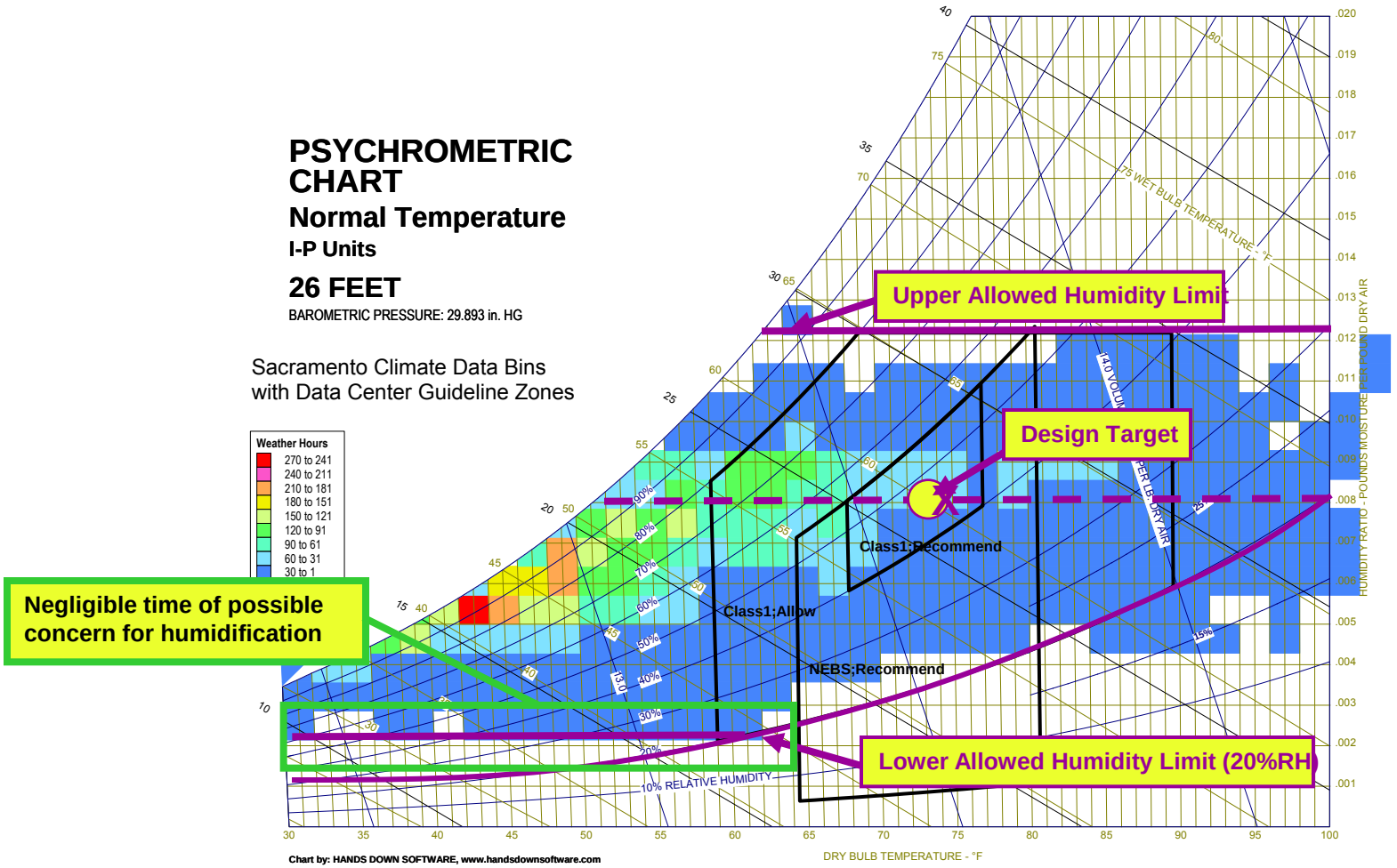
San Francisco



Los Angeles


PSYCHROMETRIC CHART
Normal Temperature
I-P Units
105 FEET
BAROMETRIC PRESSURE: 29.808 in. HG
Los Angeles Climate Data Bins with Data Center Guideline Zones
Weather Hours
396 to 353
352 to 309
308 to 265
264 to 221
220 to 177
176 to 133
132 to 89
88 to 45
44 to 1
Upper Allowed Humidity Limit
Design Target
Class1;Recommend
Class1;Allow
NEBS;Recommend
Lower Allowed Humidity Limit (20%RH
Only a few hours of possible concern for humidification
75 WET BULB TEMPERATURE - °F
10% RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

Sacramento


PSYCHROMETRIC CHART
Normal Temperature
I-P Units
26 FEET
BAROMETRIC PRESSURE: 29.893 in. HG
Sacramento Climate Data Bins with Data Center Guideline Zones
Weather Hours
270 to 241
240 to 211
210 to 181
180 to 151
150 to 121
120 to 91
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Upper Allowed Humidity Limit
Design Target
Class1;Recommend
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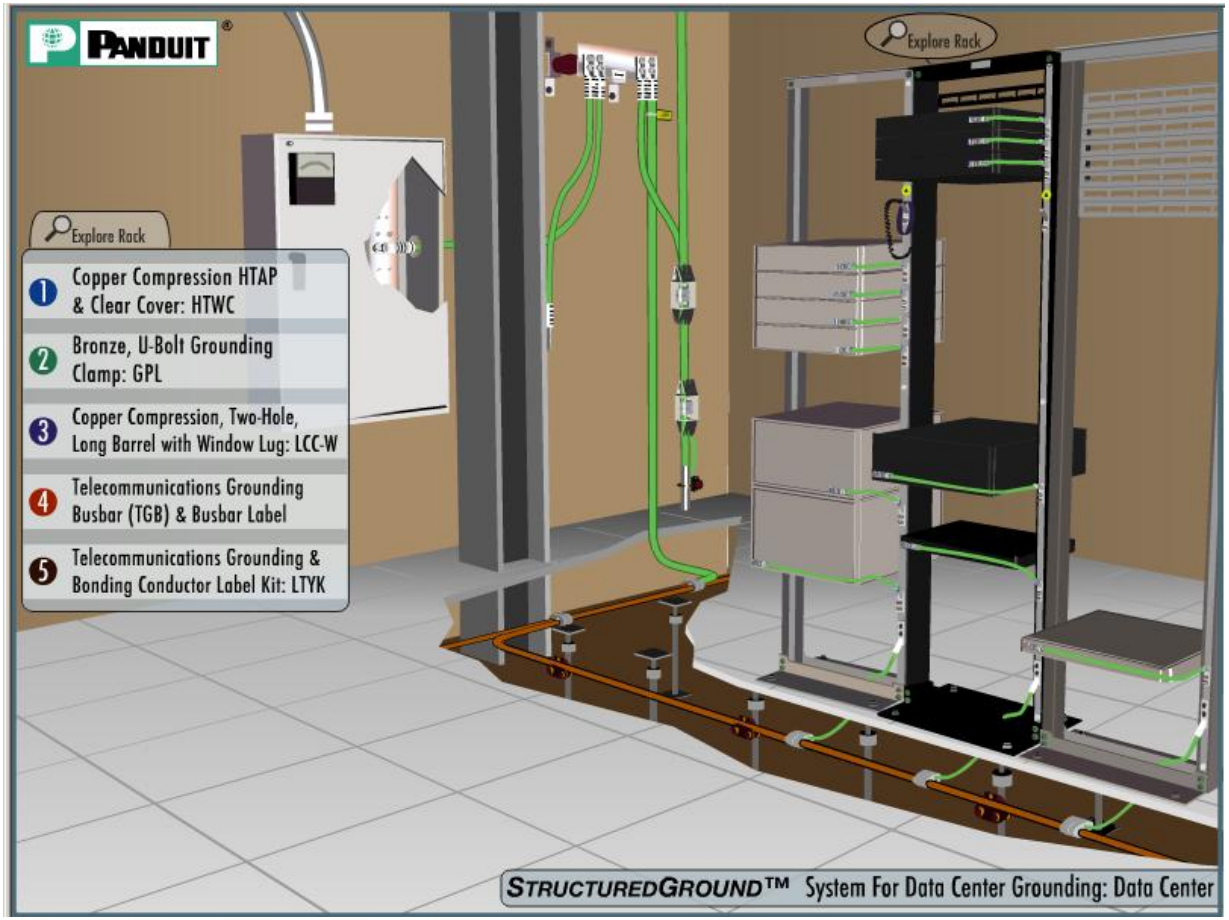
10% RELATIVE HUMIDITY
DRY BULB TEMPERATURE - °F
HUMIDITY RATIO - POUNDS MOISTURE PER POUND DRY AIR
Chart by: HANDS DOWN SOFTWARE, www.handsdownsoftware.com

Lower humidity limit

- Mitigate electrostatic discharge (ESD)
  - Recommended procedures
    - Personnel grounding
    - Cable grounding
  - Recommended equipment
    - Grounding wrist straps on racks
    - Grounded plate for cables
    - Grounded flooring
    - Servers rated for ESD resistance
  - Industry practices
    - Telecom industry has no lower limit
    - The Electrostatic Discharge Association has removed humidity control as a primary ESD control measure in their ESD/ANSI S20.20 standard
  - Humidity controls are a point of failure and are hard to maintain
  - Many data centers operate without humidification
  - This needs more research
- And for some physical media (tape storage, printing and bursting)
  - Old technology not found in most data centers
  - It is best to segregate these items rather than humidify the entire data center

ESD control: floor grounding



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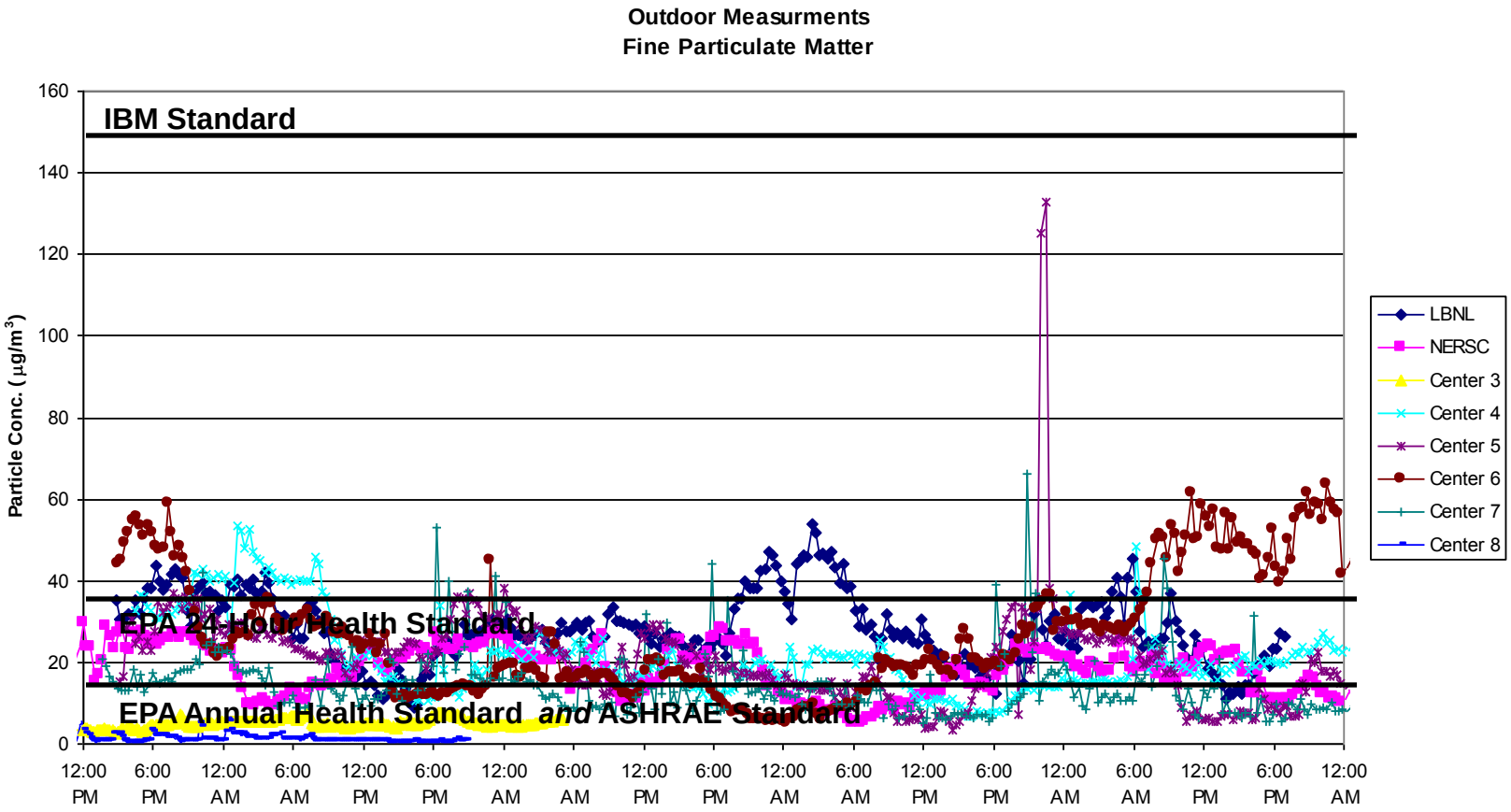
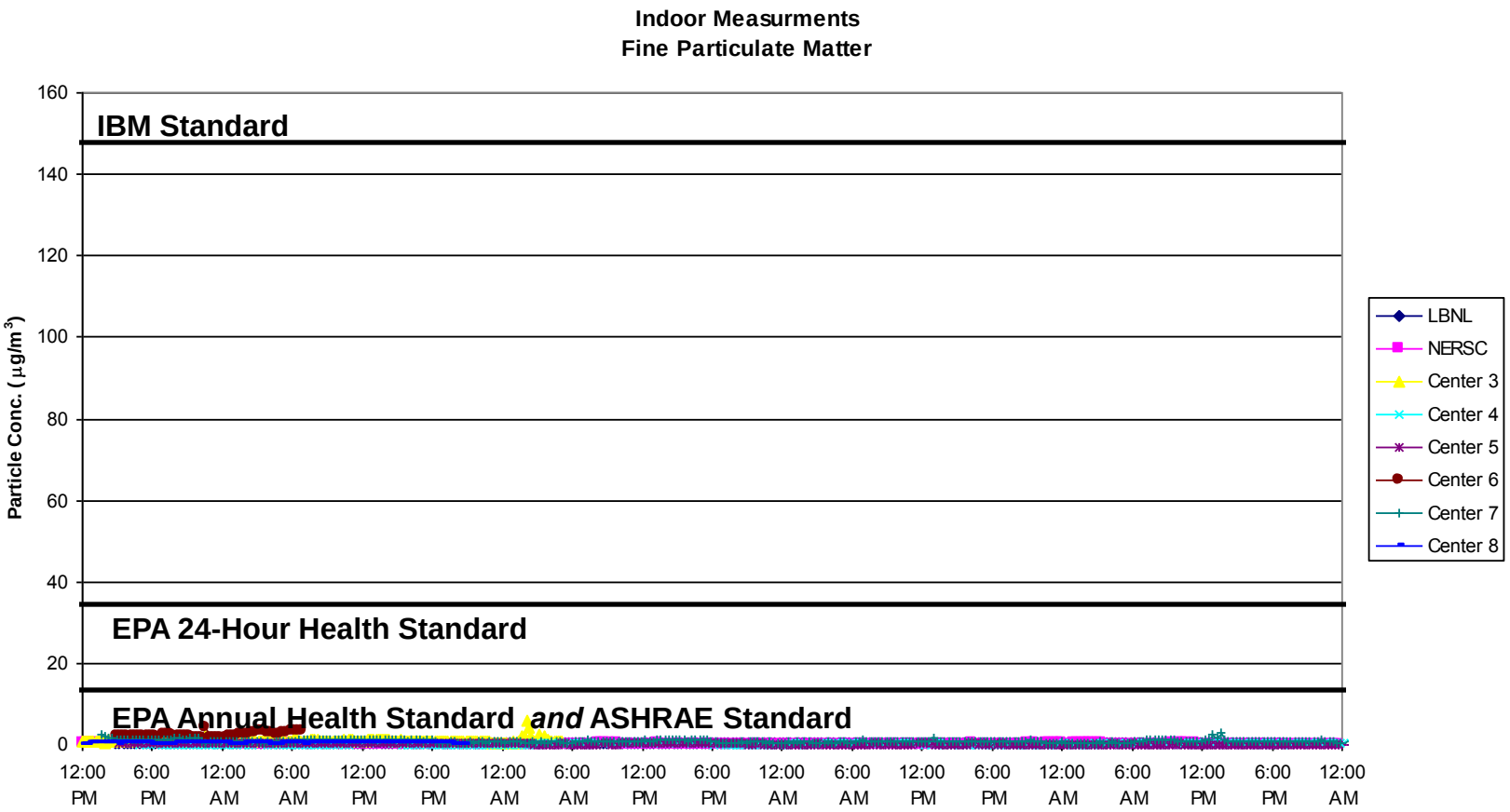
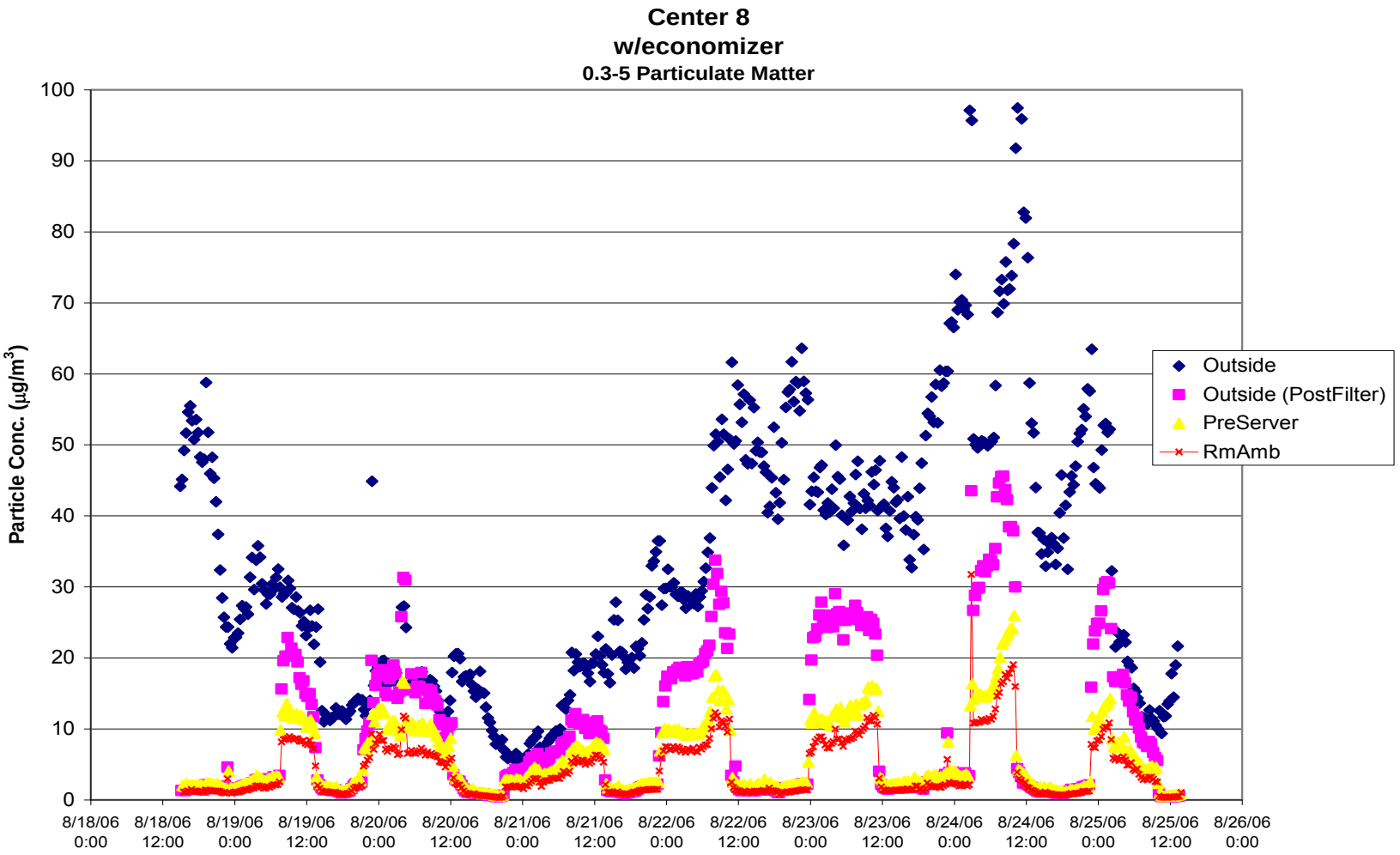
Outdoor measurements



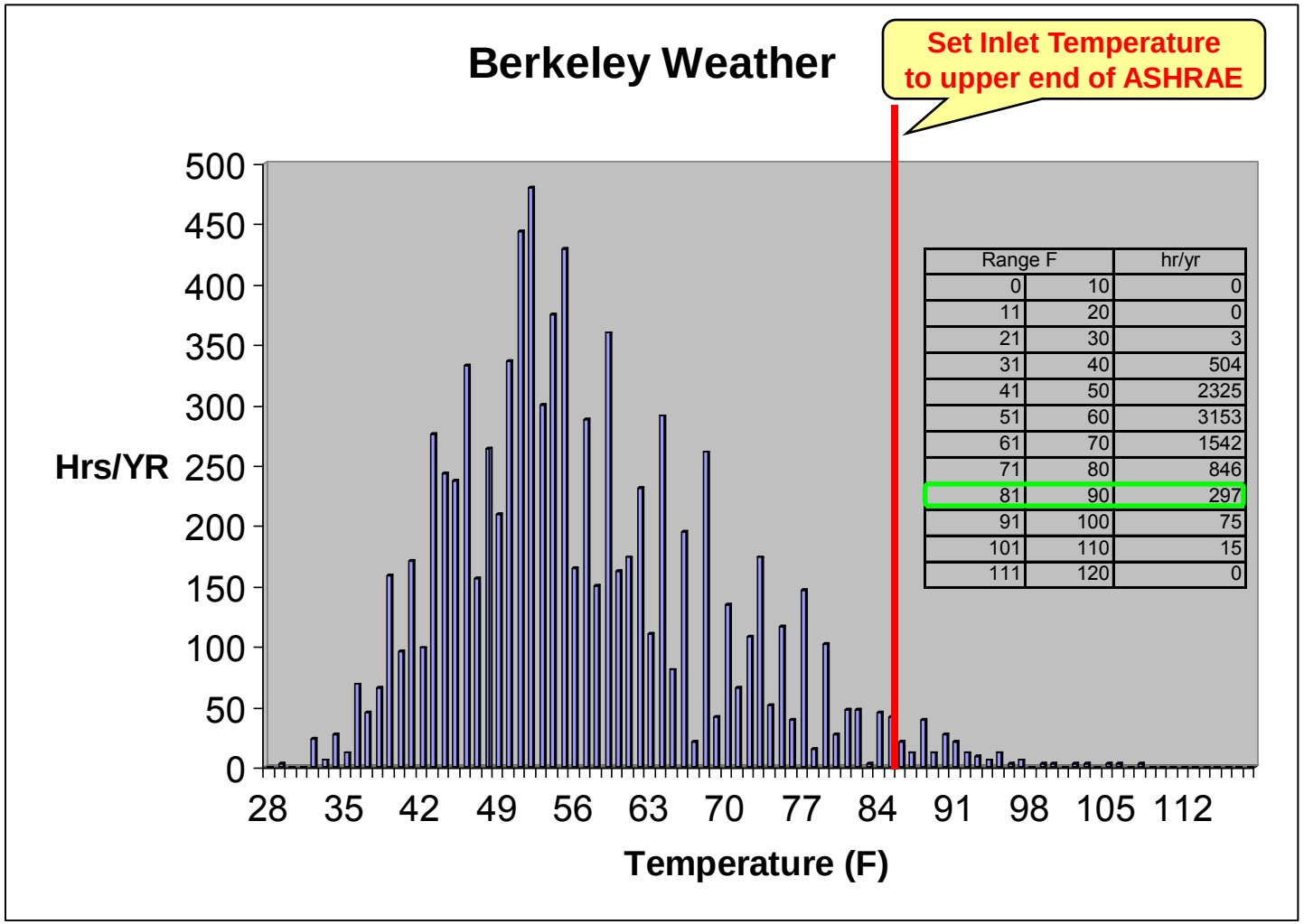
Measurements inside the centers



Data center with economizer



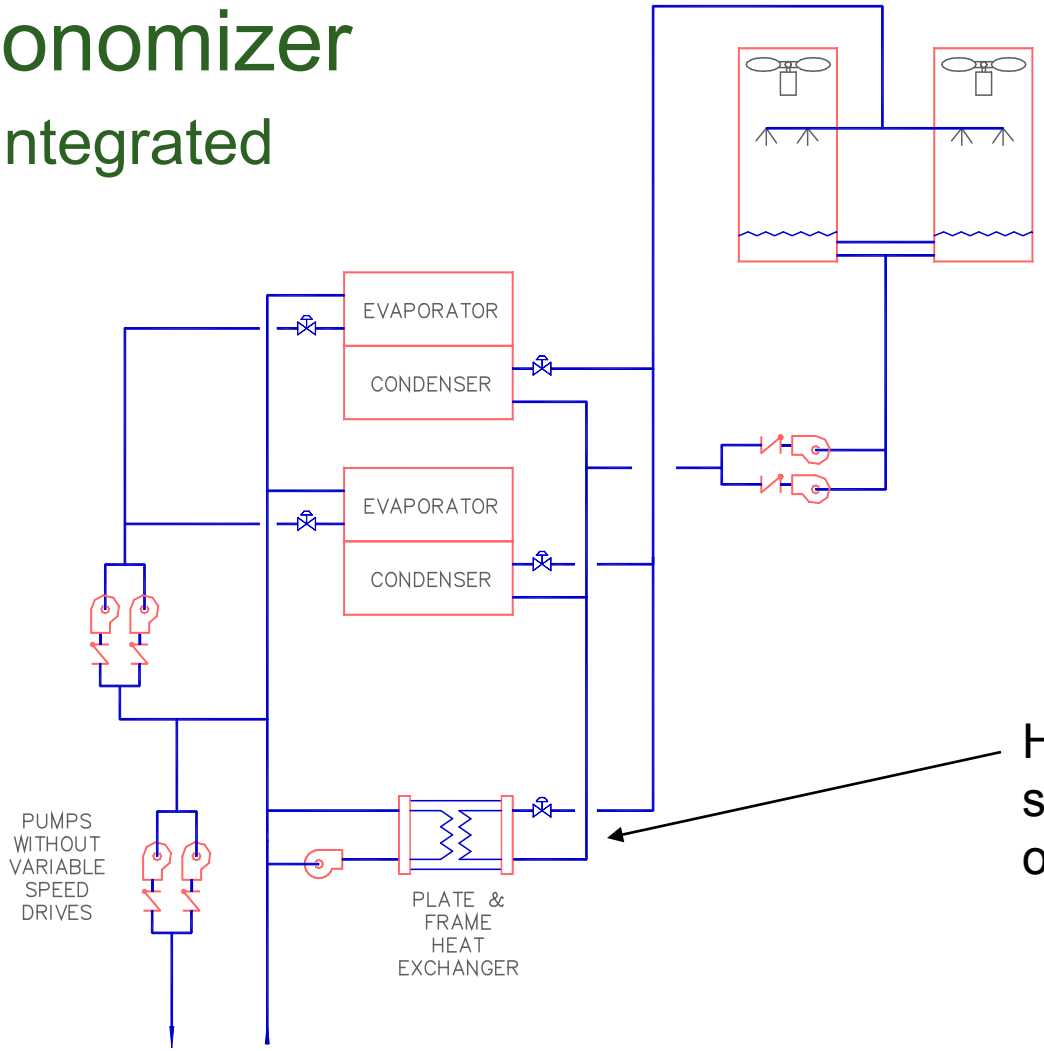
Free Cooling (Economizers)



Range F		hr/yr
0	10	0
11	20	0
21	30	3
31	40	504
41	50	2325
51	60	3153
61	70	1542
71	80	846
81	90	297
91	100	75
101	110	15
111	120	0

Water-Side Economizer

Integrated



Heat Exchanger in series with chillers on CHW side

Economizer Summary

Air-Side Economizers

- Provides free cooling when dry-bulb temperatures are below 78°F-80°F.
- May increase particulates (LBNL research indicates this is of little concern).
- Should be integrated to be most effective.
- Improves plant redundancy!
- Can work in conjunction with water-side economizers on data centers!
- Need to incorporate relief.

Water-Side Economizers

- Provides low energy cooling when wet-bulb temperatures are below 55°-60°F.
- Avoids increased particulates (and low humidity if that concerns you).
- Should be integrated to be most effective (see previous slide).
- Improves plant redundancy!
- Can work in conjunction with air-side economizers on data centers!

Both are proven technologies in data centers

A case study of two designs

- Collocation facility in the Bay Area
- Side by side designs in same facility over two phases
- Motivation for the second design was to reduce cost

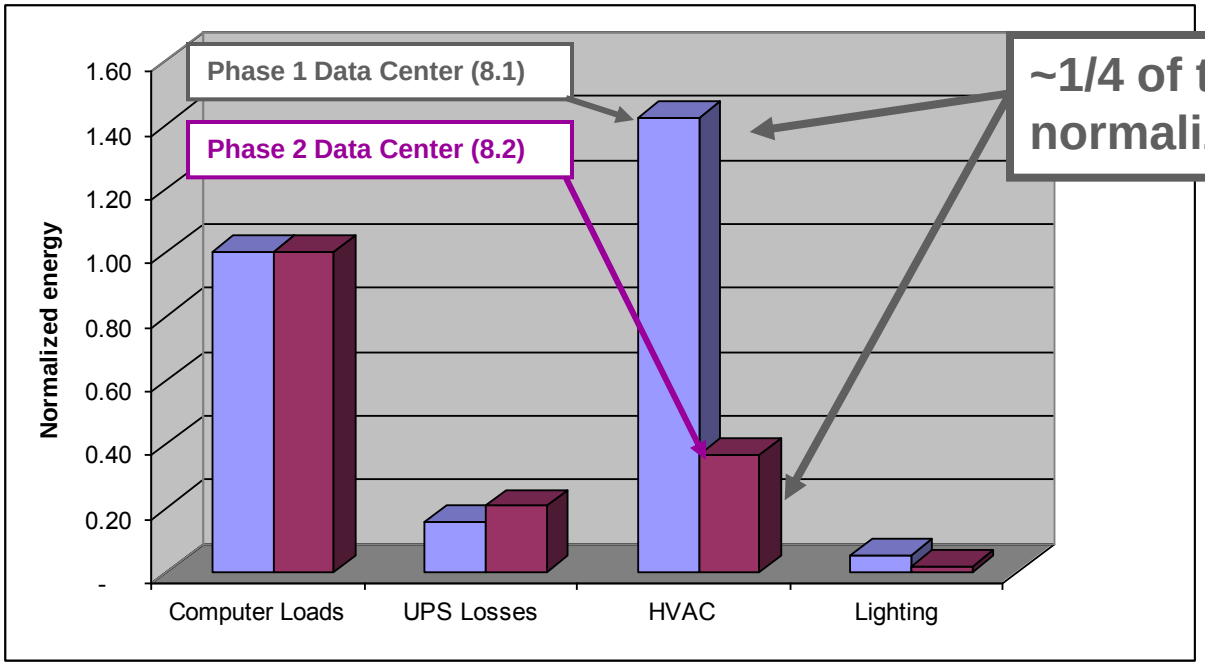
- Case study was developed by Lawrence Berkeley National Laboratory (LBNL)
  - Data Centers 8.1 and 8.2
- Both sections at ~30% build-out during monitoring

A tale of two designs: overview

- **Phase 1 Data Center (8.1)**
  - 26,200 ft2
  - 27 W/ft2 design
  - Traditional under-floor design with CRAC units
  - Air-cooled DX
  - Humidity controls (45%-55%)
- **Phase 2 Data Center (8.2)**
  - 73,000 ft2
  - 50 W/ft2 design
  - Under-floor supply from central AHUs with CHW coils
  - Water-cooled plant
  - Air-side economizers
  - No humidity controls

A tale of two designs: a closer look

Normalized efficiency metric: $\eta_{cooling} = \frac{kW_{cooling\_systems}}{kW_{servers}}$



Data normalized to computer loads

A tale of two designs: results

- **Phase 1 Data Center (8.1)**
  - Around 2x the HVAC installed cost ($/ft2)
  - Around 4x the energy bills (when normalized to server load)
  - Acoustical problems
  - Higher maintenance costs
  - Lost floor space in data center due to CRACs
- **Phase 2 Data Center (8.2)**
  - Preferred by the facility operators and data center personnel

Two data centers: summary

- What made the difference?
  - Airside economizers
  - No humidity controls
  - Water-cooled chilled water system
  - AHUs instead of CRAC units